ISRO's Scatterometery Programme

Tapan Misra, Raj Kumar, BS Gohil,
Kirti Padia and Prantik Chakraborty

SAC, ISRO

Scatterometer onboard Oceansat-II (Oscat)

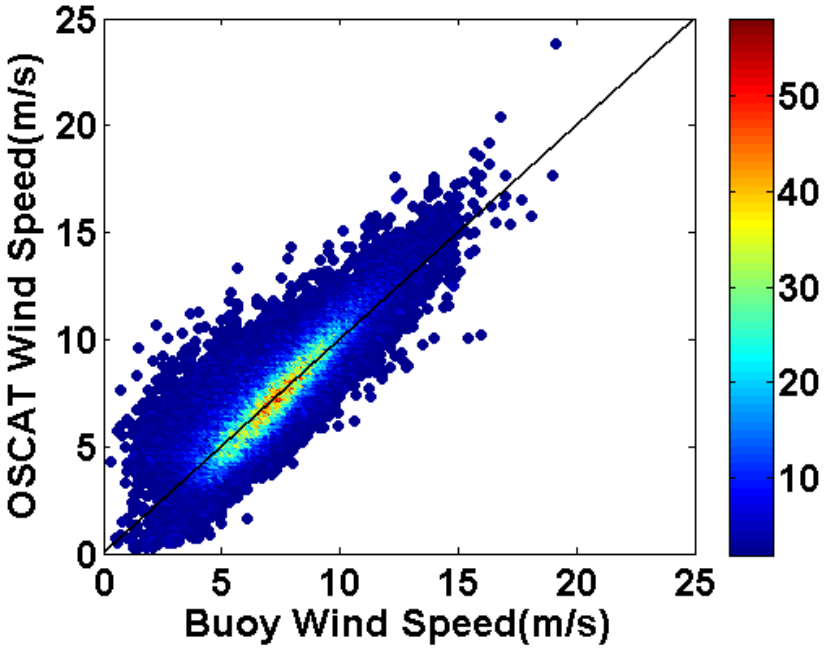
- First Active Microwave Sensor by ISRO
- Launched on 23rd Sep'2009
- Faced a hiccough initially after launch when an angular offset was discovered between the scan-angle encoder reading and the physical antenna pointing. Managed with yaw-rotation of spacecraft.
- Successfully operated for 4½ years. Data disseminated freely to international agencies e.g. NASA, NOAA, EUMETSAT, KNMI etc. Turned out to be a globally useful mission.
- Ceased to operate in April 2014 due to scan-mechanism malfunction in main chain and TWTA failure in the redundant one.

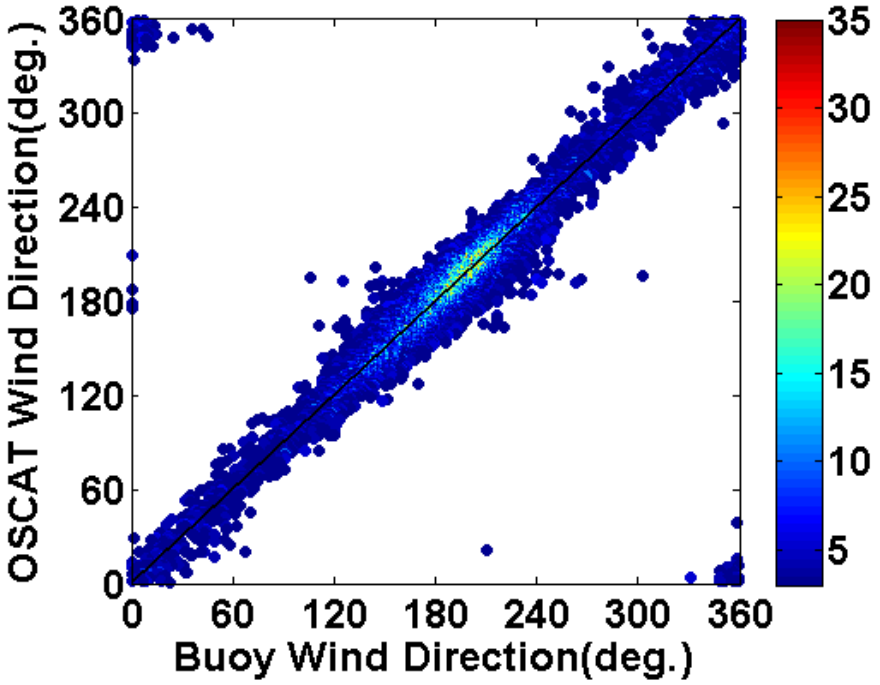
Mission Specifications	
Satellite Nominal Altitude	720 Km
Inclination	98°
Orbit type	Polar Sun Synchronous
Frequency	13.51 GHz
Polarization	HH for Inner Beam & VV for Outer Beam
Swath	1400 Km for Inner Beam & 1840 Km for Outer Beam
Wind Speed	4-24m/s with an accuracy of 2m/s or 10% whichever is higher
Wind Direction	0° to 360° (20° rms).
Wind Vector Cell (grid) Size	50 Km x 50 Km Grid

System Overview

Major System Specifications		
Antenna System	Inner Beam	Outer Beam
Shape and Size	Parabolic Dish with 1m diameter	
Gain	40dBi	40dBi
Beam Width (Az x El)	1.47° x 1.67°	1.47° x 1.67°
Look Angle	42.6°	49.3°
Incidence Angle	49°	57°
Polarization	HH	VV
Footprint	31km x 65km	26km x 42km
PSLR	Better than -16 dB	
Rotation Speed	20.5 rpm	
Angle Encoder	16 bit	
Transmitter		
Peak Power	100 W	
Center Frequency	13.51 GHz	
Bandwidth	400 KHz	
Pulse-width	1.35 ms	
Nominal PRF	193 Hz	
Modulation	LFM	
Chirp Rate	296.29 MHz/s	
Receiver		
Noise Figure	3.0 dB	
Receiver Path Loss	3.0 dB	
Output bandwidth	1.55 MHz	
Data Handling		
Quantization	8 bit I + 8 Bit Q (including sign bit)	
Processed Output	16Bit unsigned	
Receive Window Width	2.097 ms	
Sampling Frequency	1.95 MHz	

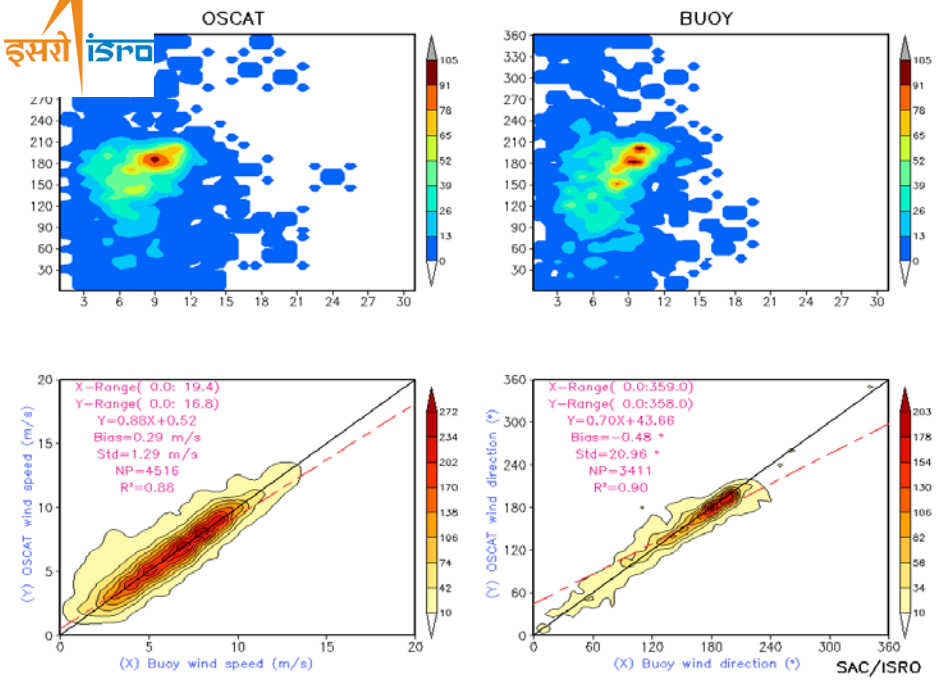
OSCAT Validation

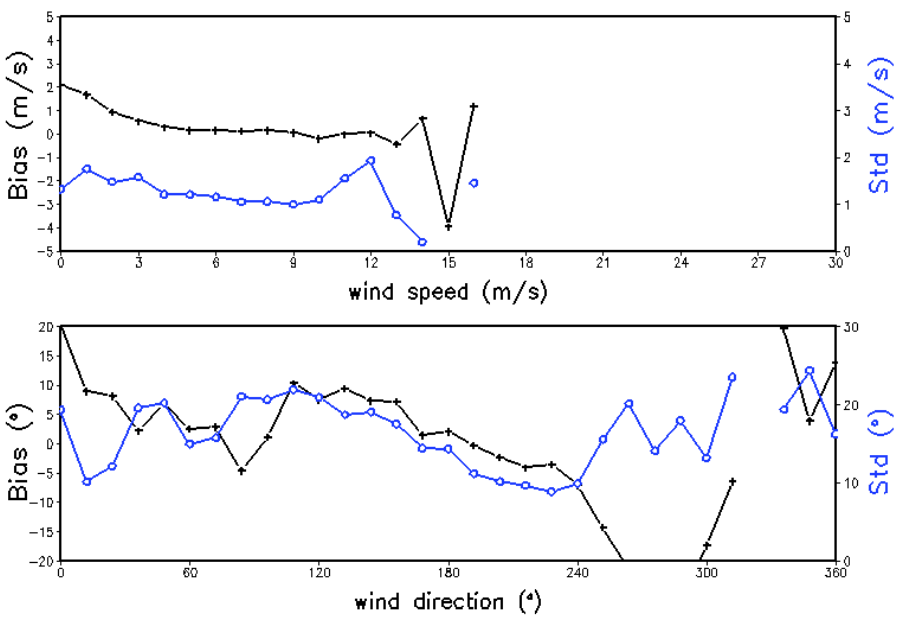




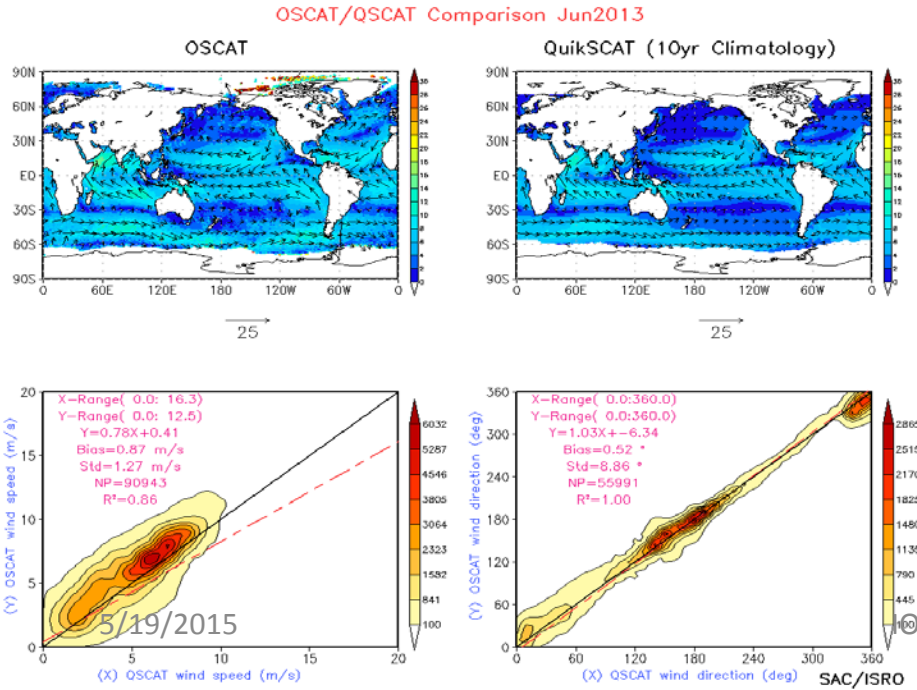
Statistics of OSCAT comparison with Buoys, Model and ASCAT for 4-24 m/s

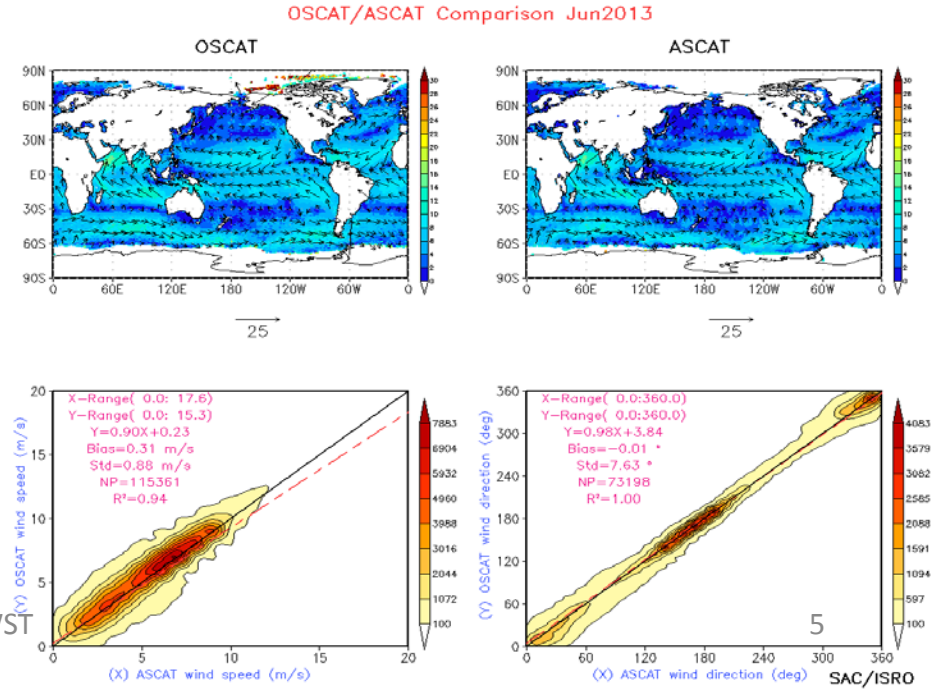
OSCAT with	Temporal Difference	No. of collocated data	Wind speed		Wind direction	
			Bias	RMSE	Bias	RMSE
Buoy	30 min	51039	0.091	1.393	-0.447	21.261
ASCAT	3 hr	9,78,455	0.19	1.14	0.49	18.39
ECMWF	6 hr	29290996	0.018	1.439	-0.69	17.16
NCEP	6 hr	33951459	-0.076	1.754	-0.46	18.83



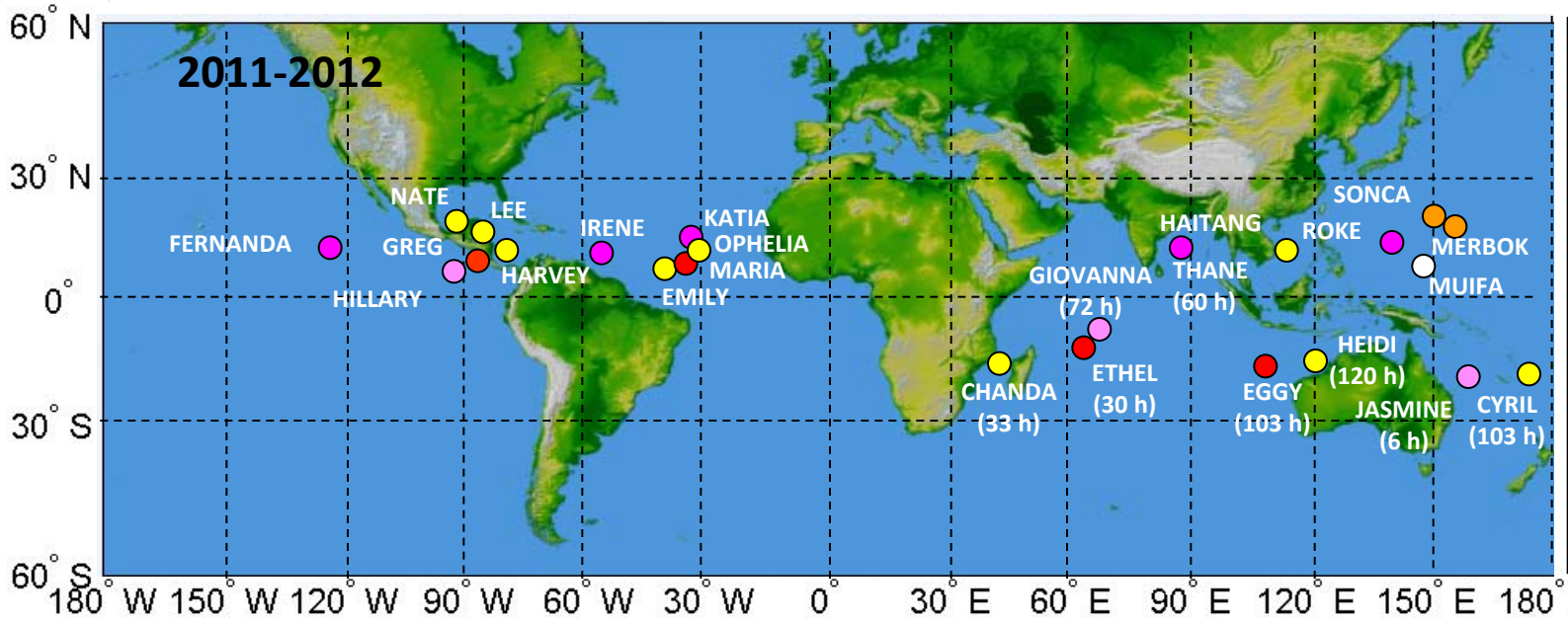


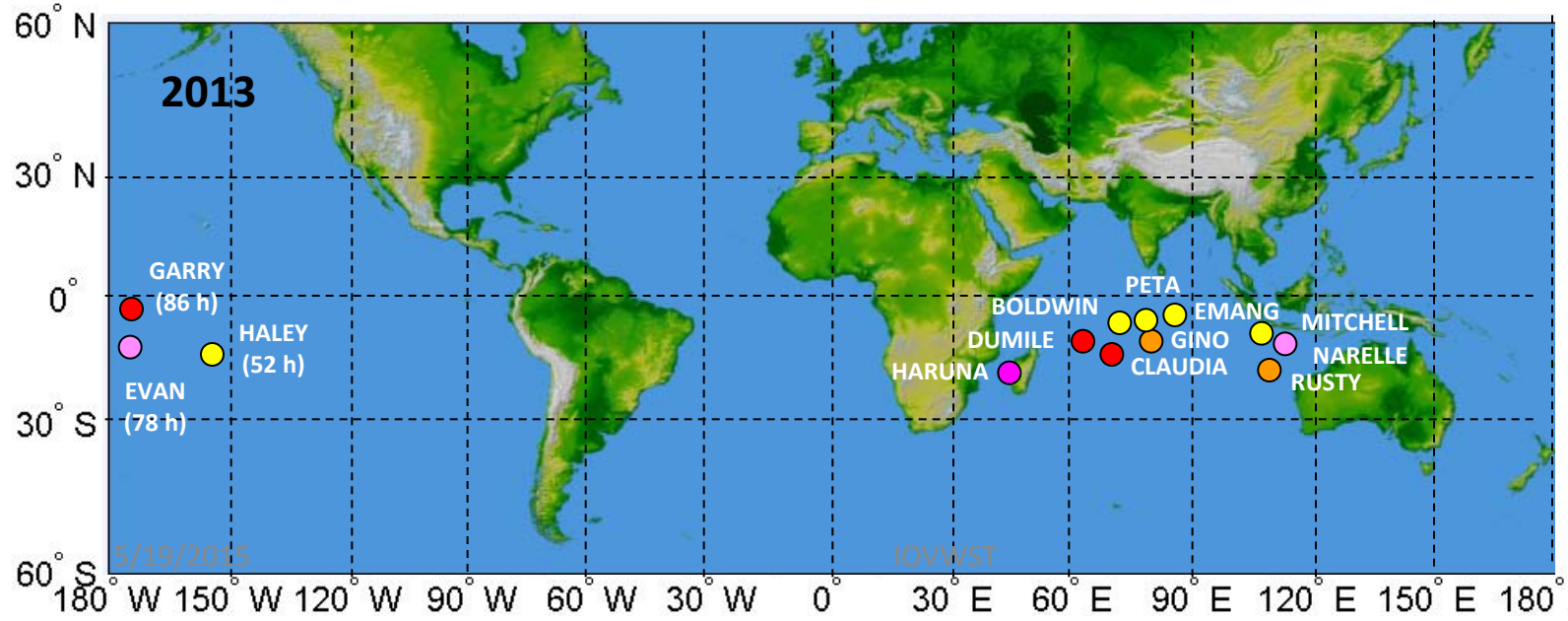
Monthly validation for June 2013





Prediction of Global Tropical Cyclogenesis using OSCAT Data (2011-2013)

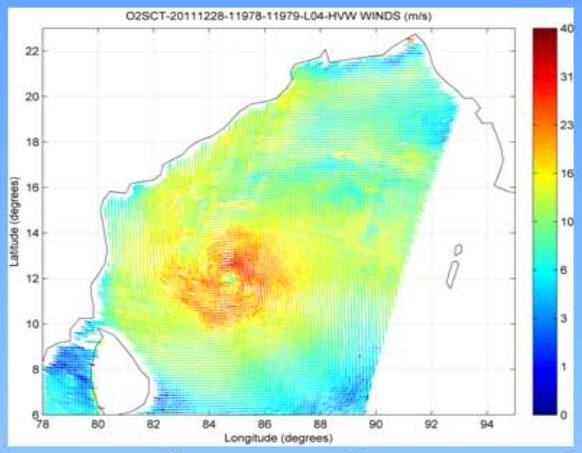




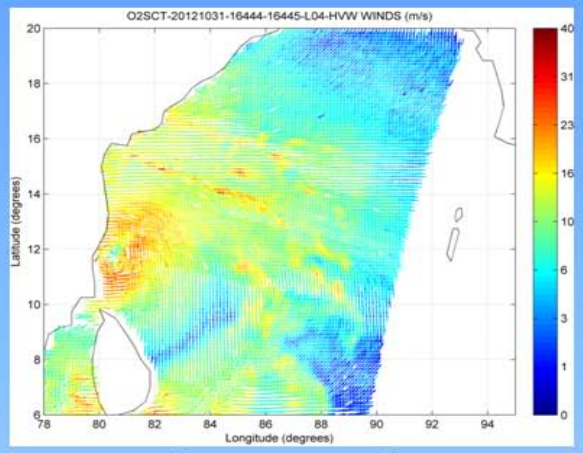
Mean Prediction Lead Time

60 Hours

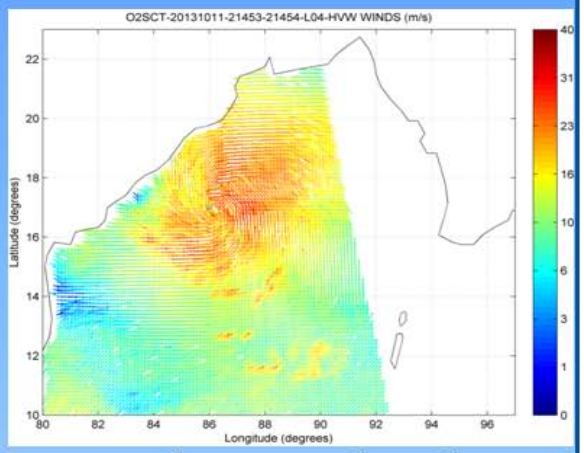
Major Cyclones Captured by Oceansat – II Scatterometer



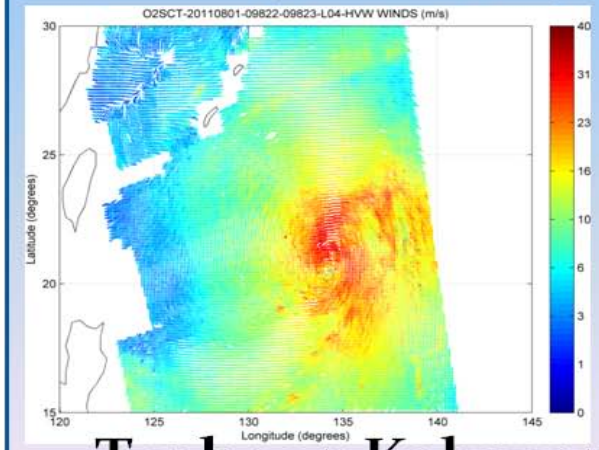
Cyclone Thane, India(28-12-2011)



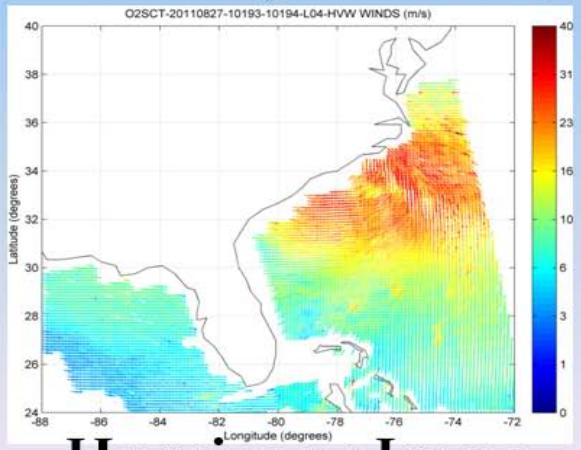
Cyclone Nilam, India(31-10-2012)



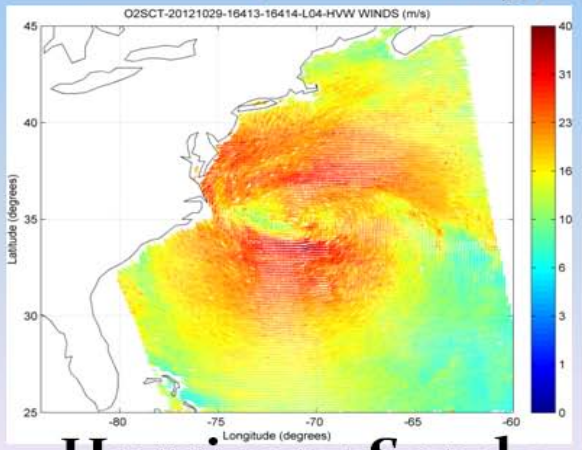
Cyclone Phailin, India(11-10-2013)



Typhoon Kabayan Phillippines(01-08-2011)



Hurricane Irene, USA (27-08-2011)



Hurricane Sandy, USA (29-10-2012)

ISRO's Observations on Rapidscat

Courtesy: Anuja Sharma, Kirti Padia and Dr. Raj Kumar

RapidScat Data Quality Evaluation Level 1B

•RapidScat Level-1B data is studied and evaluated for quality parameters in terms of static and dynamic dependency.

• ***Discontinuity in data is observed*** around the tropical region at 40° to 50° longitudes.

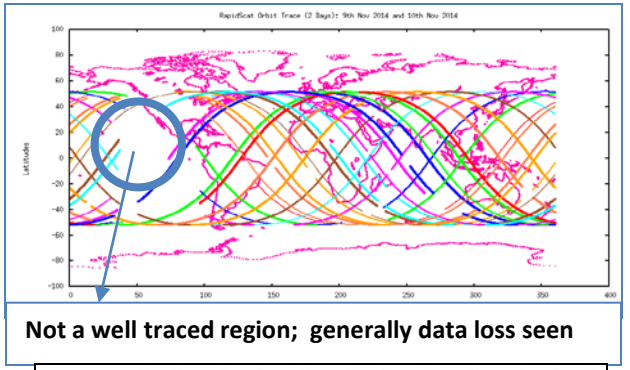
•Static parameters such as X factor component and Band width ratio are found as expected

•In case of incidence angle jumps are observed in few revolutions.

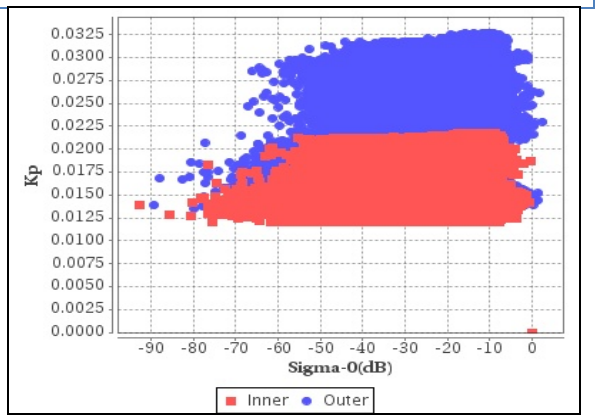
•Dynamic range for sigma-0 for the data is lying between -60 to 0 dB and brightness temperature of the order of -50 to 400 K.

•Kpc values are within the range of 0.02 to 0.1 ***which reflects good sigma-0 performance***.

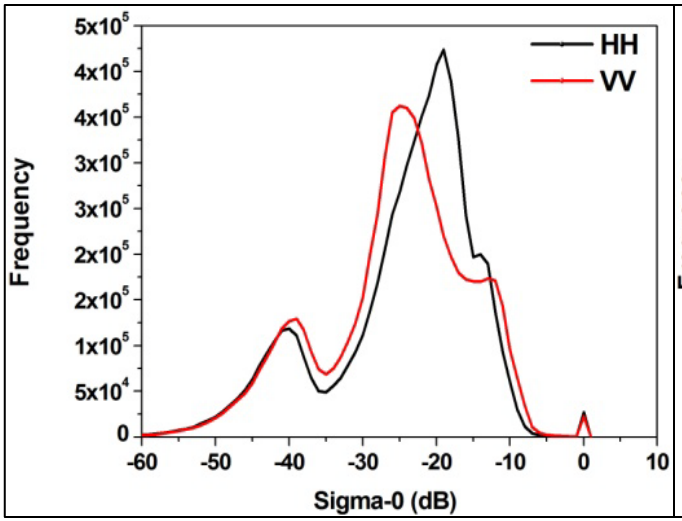
•Variation in SNR with respect to sigma0 shows expected linearity for both the beams.



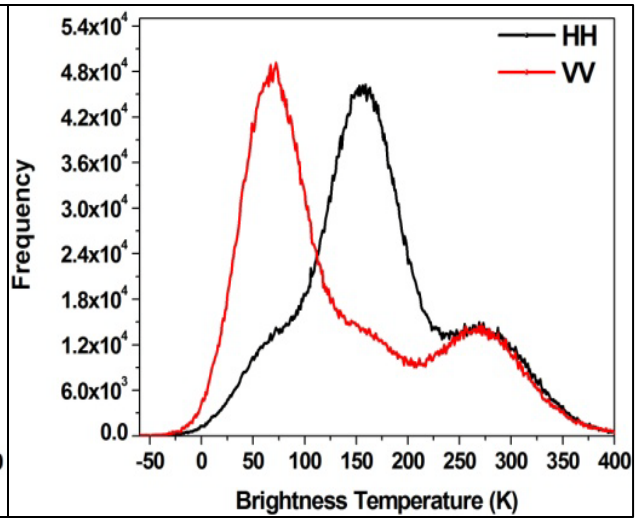
Not a well traced region; generally data loss seen



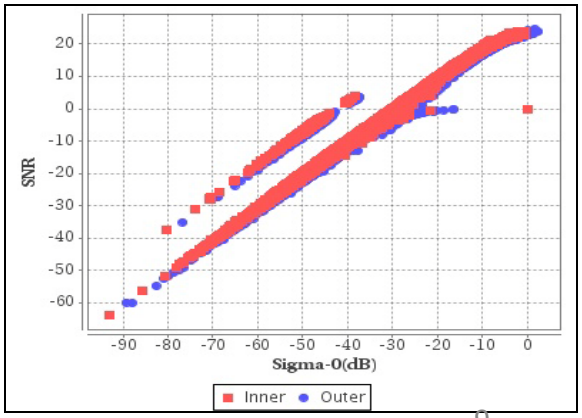
Sigma 0 v/s Kp



Sigma 0 Histogram



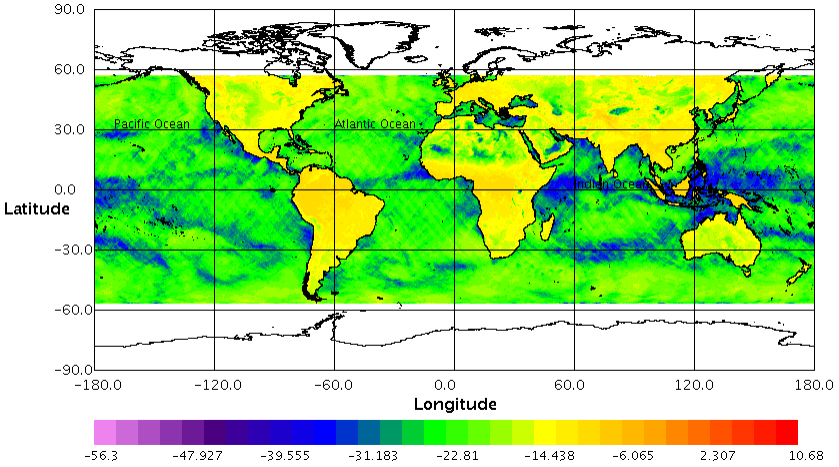
BT Histogram



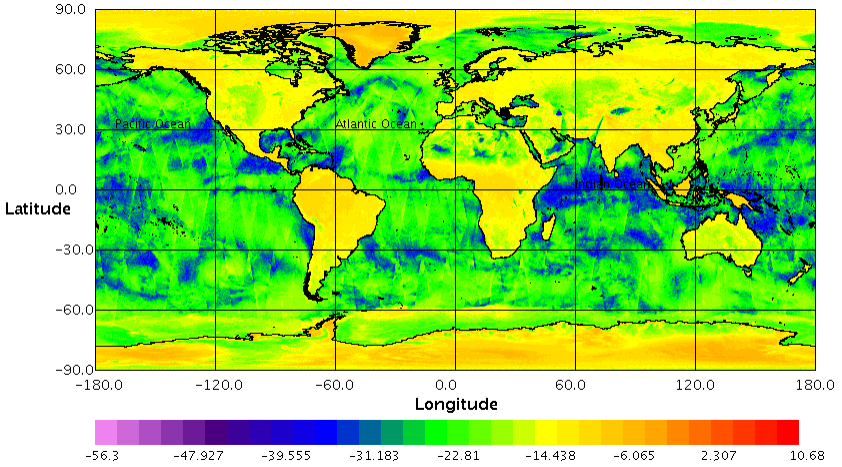
Sigma0 v/s SNR

Comparison of sigma0

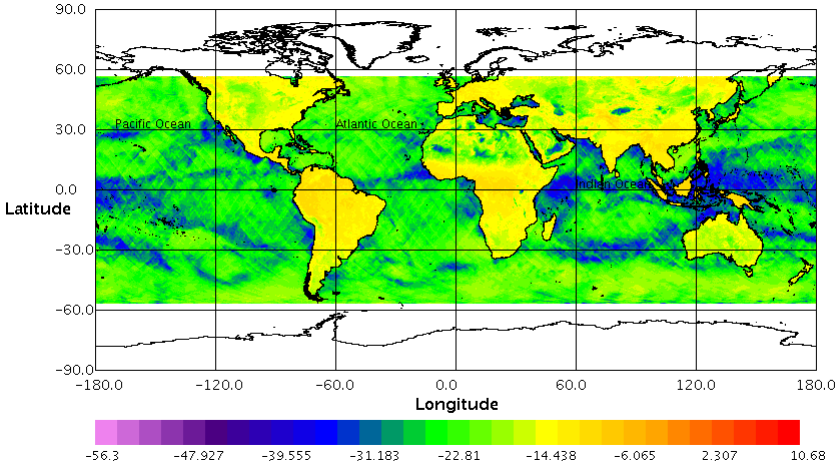
- Variation of mid slice sigma0:



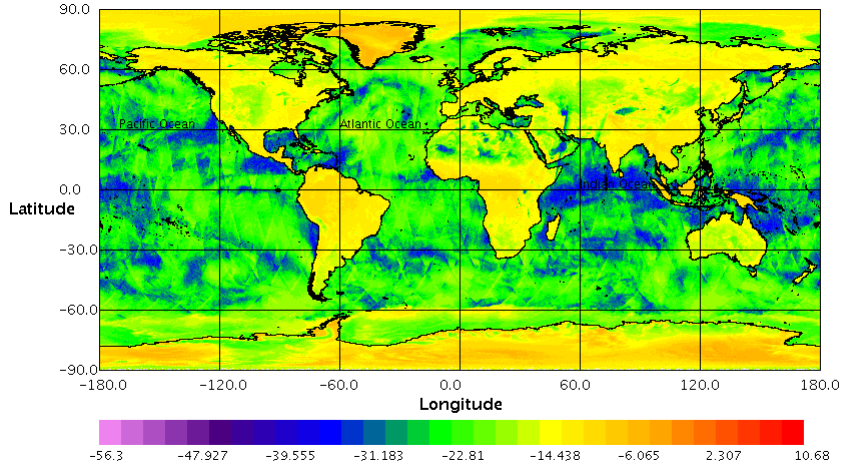
RAPIDSCAT VVFORE sigma0



OSCAT VVFORE sigma0



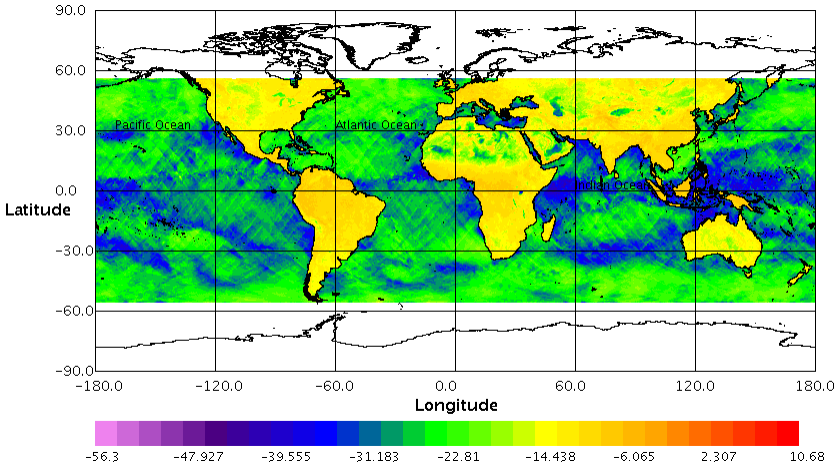
RAPIDSCAT VVAFT sigma0



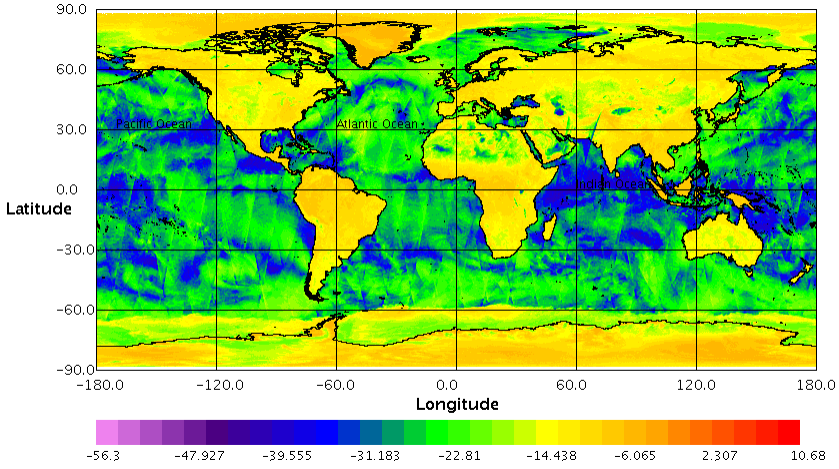
OSCAT VVAFT sigma0

Comparison of sigma0

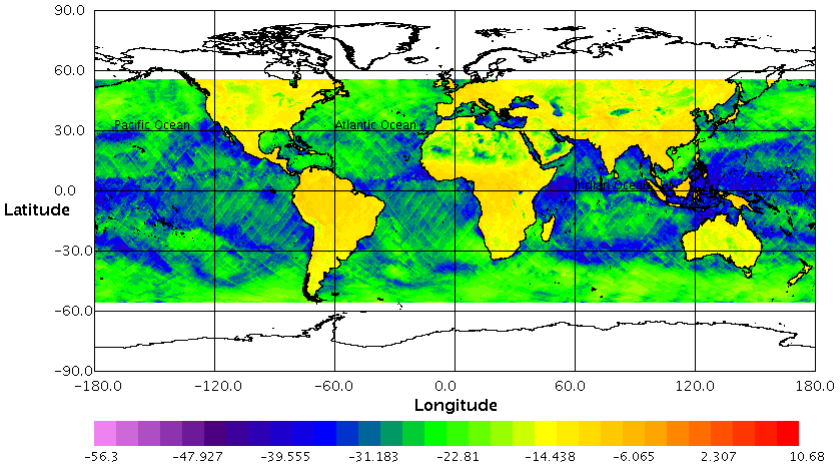
- Variation of mid slice sigma0:



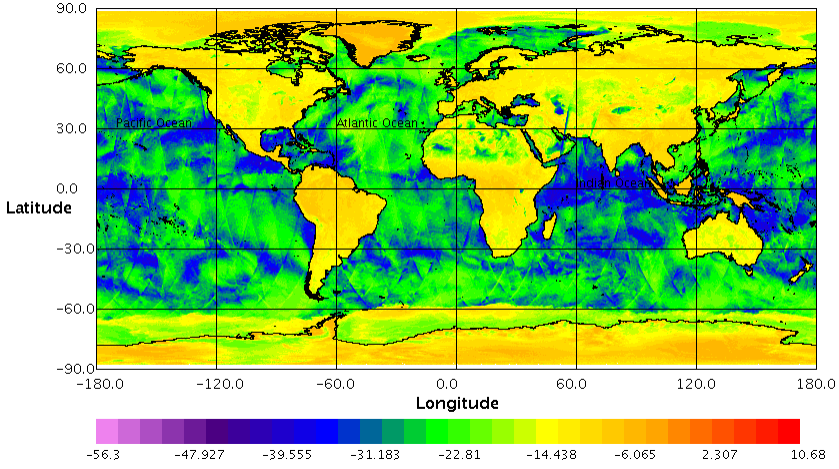
RAPIDSCAT HHFORE sigma0



OSCAT HHFORE sigma0



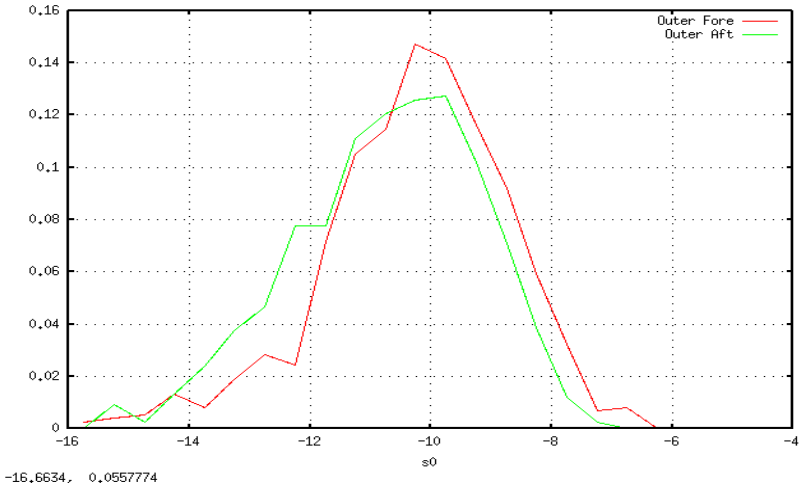
RAPIDSCAT HHAFT sigma0



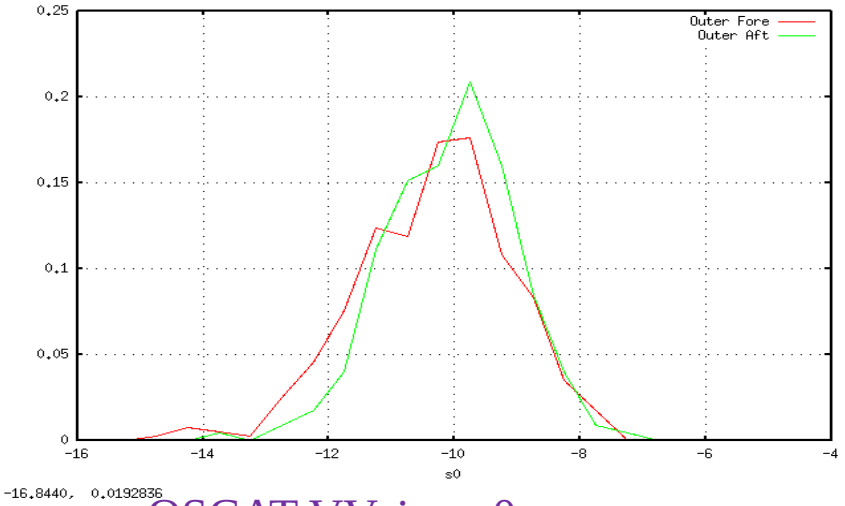
OSCAT HHAFT sigma0

Comparison of sigma0

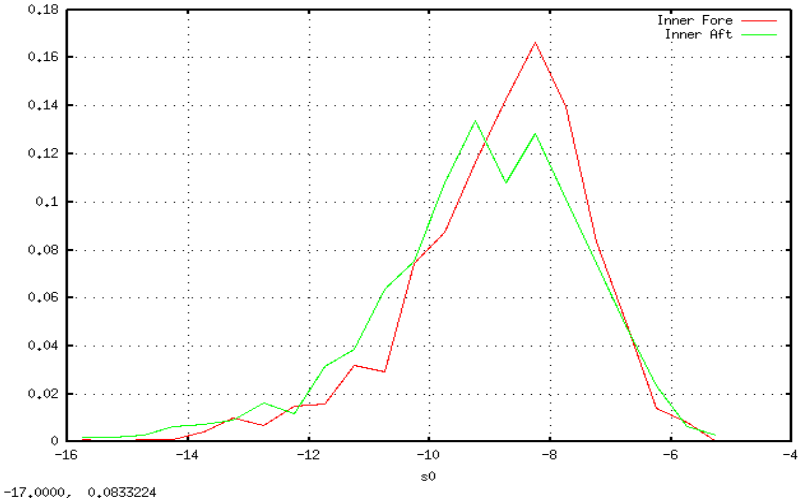
- Variation in histogram of Amazon region (bin size=0.5dB) :



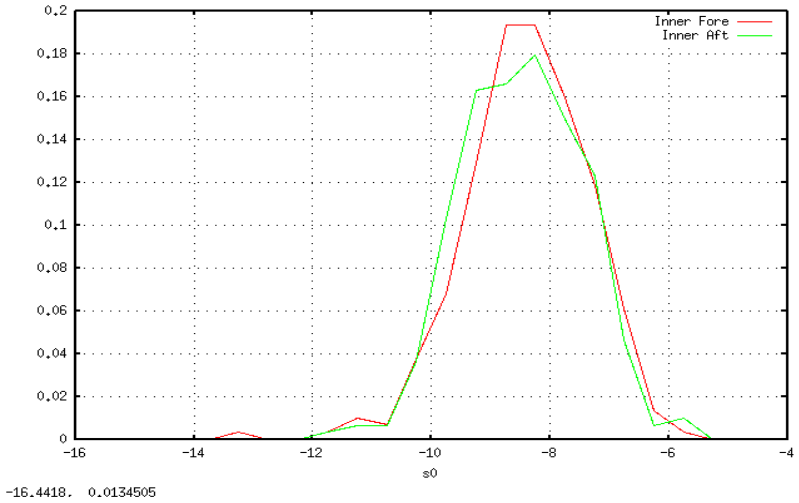
RAPIDSCAT VV sigma0



OSCAT VVsigma0



RAPIDSCAT HH sigma0

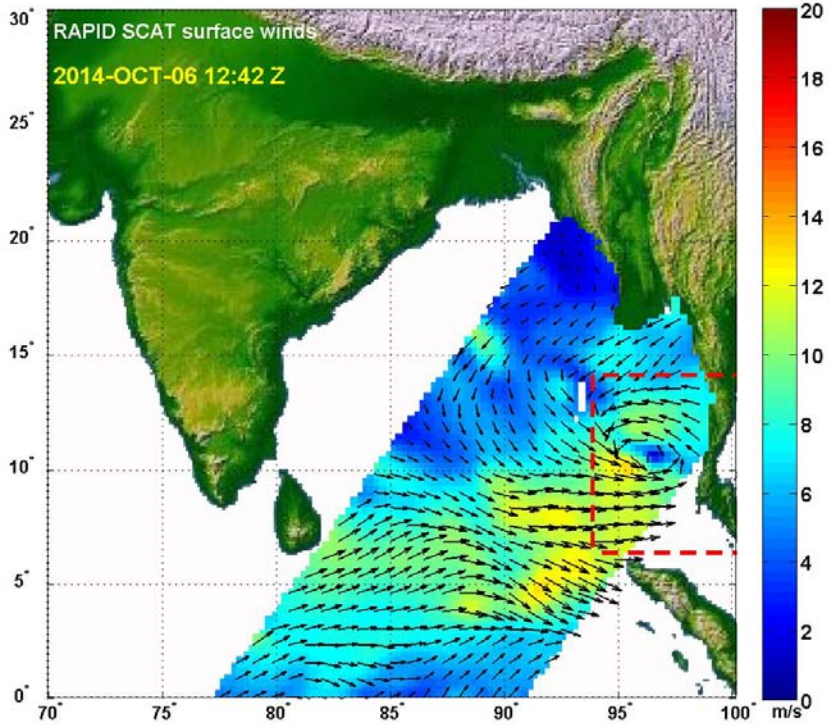


OSCAT HH sigma0

Cyclogenesis Prediction using RAPIDSCAT Data

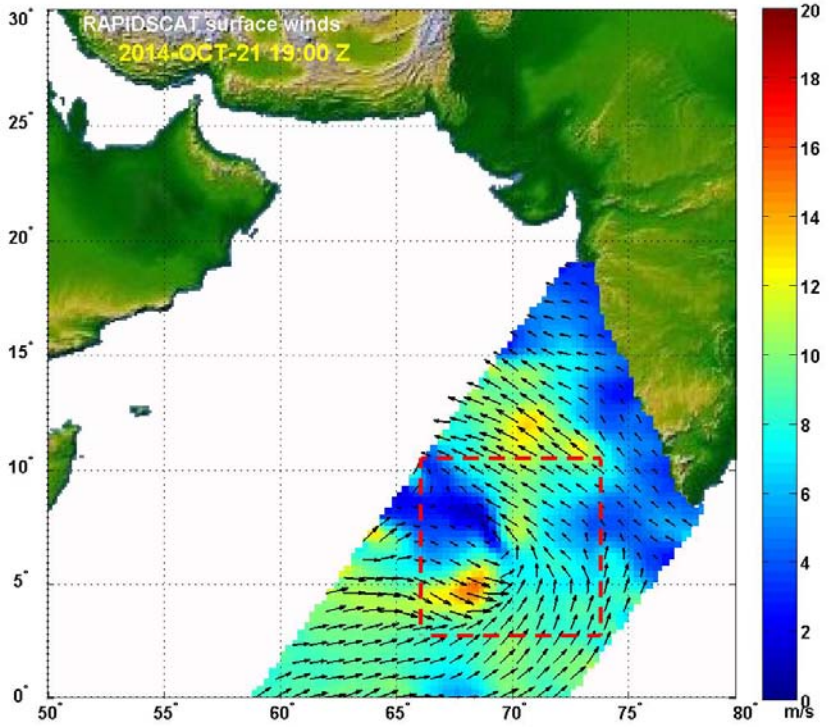
Cyclogenesis prediction using wind pattern matching based approach

Prediction of cyclone HUDHUD (8-12 October, 2014)



Cyclone Formation : 8 OCT, 00 Z
Cyclogenesis prediction: 6 OCT 13 Z
Prediction lead time: 36 hour

Prediction of cyclone NILOFAR (25-30 October, 2014)



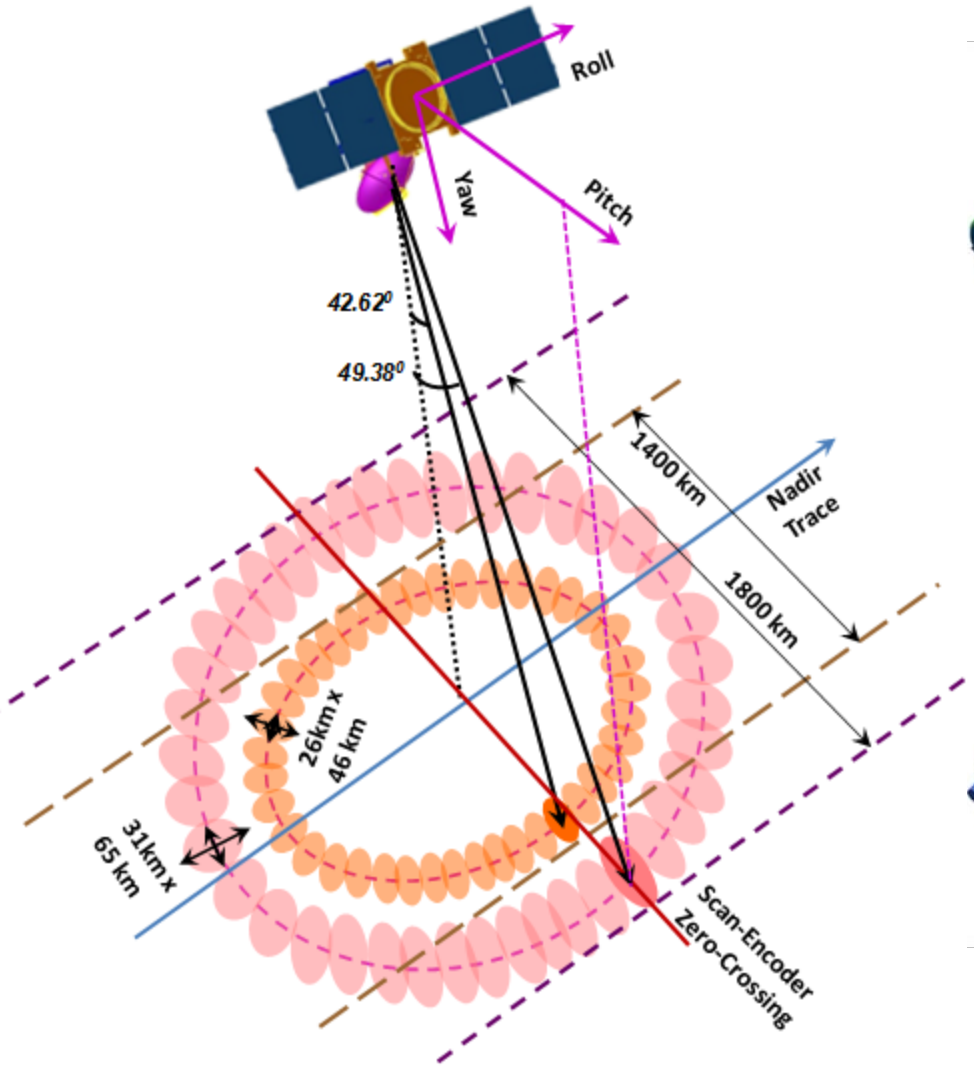
Cyclone Formation : 25 OCT, 12 Z
Cyclogenesis prediction: 21 OCT 19 Z
Prediction lead time: 90 hour

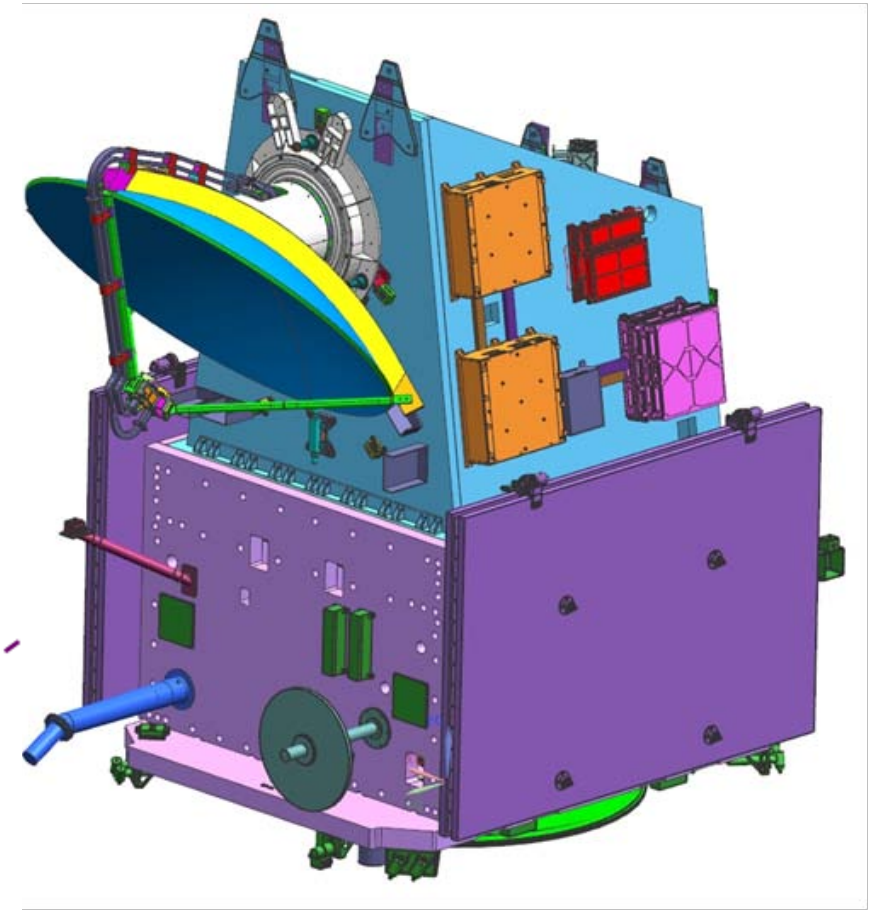
Scatsat-1 : Oscat Follow-on Mission (2016)

Scatsat-1 Mission Specifications

Spacecraft Altitude	720 Km (Nominal)
Orbit	**Non-Sun Synchronous at launch ; To be arrested within 3-6 months from launch. Tentative local pass time: 8am/8pm**
Platform	**IMS-II**
Frequency	13.515625 GHz
Polarization	HH for inner and VV for Outer beams
Swath	1400 Km (both HH and VV beams available) 1400-1800 km (only VV beam available)
Wind Speed Range	**3-30ms/s**
Wind Direction Range	0° to 360°
Wind Speed Accuracy	**1.8 m/s** rms or 10% whichever is higher
Wind Direction Accuracy	20^0 rms
Wind Vector Cell (grid) Size	**25 Km x 25 Km Grid**

Scatsat-1 Scan-Geometry and CAD-Model





Antenna Offset problem: OSCAT and Scatsat-1

Problem Definition:

1. **Actual antenna azimuth pointing was offset by 210^0 with respect to +ive Pitch axis and scan-angle encoder zero-crossing**
2. **This led to erroneous onboard Doppler Frequency compensation of the echo signal resulting in the echo migrating out of the processing bandwidth to the noise-only sidebands.**
3. **180^0 offset corrected by altering sign of Doppler centroid. S/c rotated about yaw by 20^0. 10^0 offset remained throughout its life**

Measures Adopted in Scatsat-1

Marking and matching of axes and hardware features at all the interfaces and mechanical drawings.

Mechanical Alignment of antenna azimuth-pointing towards first footprint location in a scan with positive axis will be verified with simultaneous angle-data acquisition from encoder. Angle-data acquisition in static mode is a new feature in Scatsat-1.

Exigency Handling Features in Onboard Processor

I. Completely programmable Doppler Frequency Computation with angular offset provision both on El and Az
II. Programmable Processing Bandwidth (S+N) and Noise-only Bandwidths (N1 & N2)
III. Programmable Positioning of S+N and N1,N2 bands

Improvements over OSCAT

Other issues observed in Oscat	Measured adopted in Scatsat-1
SSM-Main and TWTA-Redundant failures caused mission shutdown	Cross-Patch Architecture : FG and TWTA PLC and SCE
Data Saturation near Poles	Full 32-bit Processed Data Precision
Systematic Transmit Calibration Power variation over an orbit. One-time dip in Tx Cal Power	Power at FESA Transmit Ports and Cal-port measured with temperature excursion during TWTA requalification tests. Alternative cal-measurement being explored
Scan-Mechanism Malfunction and failure	New Motor Design: More torque with less current; Shaft Material Changed from Ti alloy to SS for better conductivity

Improvements over OSCAT

Additional Features for Improvement of System Performance	
OSCAT	Scatsat-1
Scan-Angle Dependent Biases Observed. One reason is Passband Slope of Rx output SAW Filter	Output SAW Filter in Rx is being replaced with Digital domain Filter for better passband flatness
Rejection at Sampling Frequency was poor (-3dB)	With Digital Filter, Stopband rejection will be better than -20dB
Overlapped Periodogram (1K FFT) in the onboard Processor	FFT at the finest resolution (4K points, 476 Hz)
Rx Noise Figure was 3dB with cable connection between FESA and LNA	Rx Noise Figure (with new MMIC-based LNA) improved to 2.5 dB and input changed to waveguide. Net improvement in system noise figure ~ 1dB
Rotary Joint Leakage observed. RTV showed peel-off in SSM life-test model	New Rotary Joint designed: Fewer joints, Improved Insertion Loss and Less Leakage

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Missions in Pipeline

Missions	Remarks
Oceansat-3 Series: 3A, 3B, 3C	➢3 satellites to be launched in intervals of approximately 3 years starting from 2018
	➢Bus and Payload configurations to be standardized in order to reduce production cost and time
	➢WV Product Service Continuity Missions
	➢Higher-Resolution Feasibility being Explored
Dual Frequency Scatterometer	Proposed ISRO-NASA-JAXA Collaboration

THANKS